Extending the Information Power Grid Throughout the Solar System

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September 2000

Humanity is Gaia's ticket to the stars
(Dinosaurs weren’t space-faring)

http://www.nas.nasa.gov/~globus/papers/AIAAspace2000/AIAAspace2000.html

Abstract

- **IPG value to Solar System exploration**
  - help reduce launch costs and failure rates
  - support automation necessary to exploit solar system exploration by thousands of spacecraft
- **Problems:**
  - low bandwidths
  - long latencies
  - intermittent communications
  - automated spacecraft requiring computation
- **One solution: terrestrial proxies**

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One Building, then the Solar System

NAS

- Single building
- A few supercomputers
- Many workstations
- Mass storage
- Visualization
- Remote access

IPG

- Nation wide
- Many supercomputers
- Condor pools
- Mass storage
- Instruments

This talk

- Solar system wide
- Terrestrial Grid
- Satellites
- Landers and Rovers
- Deep space comm.

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Object Oriented Grid

- **Legion (University of Virginia)**
- **IPG: object oriented Grid programming environment**
- **Each hardware or software resource is a object.**
  - Independent, active, communicate asynchronously.
- **Class objects create new instances, schedule, activate, and provide metadata.**
- **Users can define and build class objects.**

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Relevant IPG Research

- **Reservations**
  - insure CPUs available for close encounter
- **Co-scheduling**
  - insure DSN and CPU resources available
- **Network scheduling**
- **Proxies for firewalls**
  - Extend to represent remote spacecraft to hide:
    - low bandwidth
    - long latency
    - intermittent communication

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Launch: the Key

- **Shuttle $22,000/kg, ~1% failure rate**
- **Commercial launchers, ~= cost, higher failure rate**
  - Exception: Russian Proton reported $2600/kg
    - Nearly meets NASA 2010 goal $2200/kg
- **Saturn V: 100 ton to LEO @ significantly less person-hours/kg**
  - Launched Skylab space station with one flight
- **Commercial airlines: ~$10/kg, ~1 fatal failure per 2,000,000 flights, 100s million persons/yr**
- **This is the problem.**

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Launch Data Systems

- **Space Shuttle Independent Assessment Team (SIAT): major opportunities for information technology.**
  - Wiring trend data were very difficult to develop.
- **Surprisingly large fraction of launch failures are directly attributable to information technology failures.**
  - Sea Launch second flight.
- **NASA 2020 goal: $220/kg to orbit with a 0.01% failure rate, enabling space tourism**
  - Will require much better RLV data systems

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IPG Launch Data System Vision

- Complete database: human and machine readable
- Software agent architecture for continuous examination of the database
- Large computational capabilities
- Model based reasoning
- Wearable computers/augmented reality
- Multi-user virtual reality optimized for launch decision support
- Automated computationally-intensive software testing

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Solar System Exploration

- **High launch cost of launch = small number exploration satellites**
  - one-of-a-kind personnel-intensive ground stations.
- **Model based autonomy = autonomous spacecraft**
- **Requirement drivers**
  - Autonomous spacecraft use of IPG resources
  - low bandwidths
  - long latencies
  - intermittent communications

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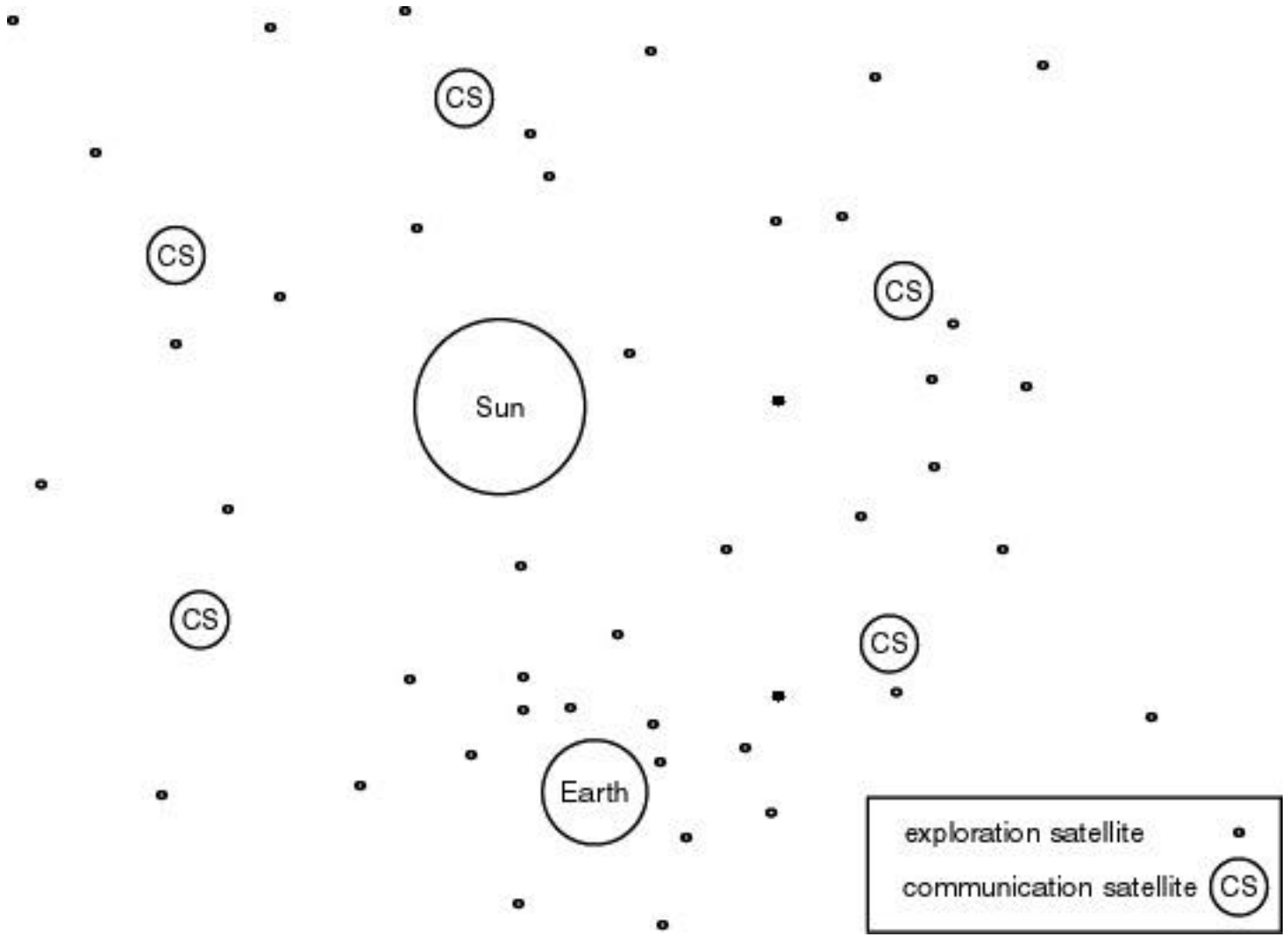
NEO Characterization Project

- 900 >1km diameter, 1,000,000,000 ~100m



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Each Spacecraft, Lander, and Rover

- **Represented by an on-board software object.**
- **Communicates with terrestrial proxies to hide communication problems**
  - know schedule for co-scheduling and reservations
- **Data stored in Web-accessible archives**
  - virtual solar system
- **Controlled access using IPG security for computational editing**

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Spacecraft Use of IPG

- **Autonomous vehicles require occasional large-scale processing**
  - trajectory analysis
  - rendezvous plan generation
  - surface hardness prediction for choosing sampling sites
- **Proxy negotiates for CPU resources, saves results for next communication window**
- **Proxy reserves co-scheduled resources for data analysis during encounters**

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Summary

- **IPG vision is an integrated nationwide network of computers, databases, and instruments.**
- **IPG throughout the solar system**
  - improve launch costs and failure rates
  - support thousands of automated spacecraft
- **Low bandwidth, long latencies, intermittent communications may be handled by proxies**
- **Proxies can also gather IPG resources to service autonomous spacecraft needs**
- **Reach for the Stars!**

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